Alfvén Eigenmodes in Enhanced $D_\alpha$ H-mode in Alcator C-Mod

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Unstable High Frequency TAEs in EDA H-mode

- Toroidal Alfvén Eigenmodes with $f_{TAE} \sim 600$ kHz correlate with QCM
- These TAEs only occur in ICRF heated H-mode not in L-mode
The QC mode and the TAEs all rotate in the electron direction.

These TAEs have toroidal mode numbers $6 \leq n \leq 11$. 
Choose Dominant Mode for Stability Analysis

- Dominant TAE peaks at about $t = 0.94$ s with $\langle \tilde{B}_\theta \rangle \sim 150$ mG and $n = 10$
- Choose this mode for stability analysis using the NOVA-K code and compare with the L-mode time at $t = 0.76$ s where the mode is stable

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NOVA-K finds a spatially broad $n=10$ mode at $478.3$ kHz $\rightarrow 100$ kHz Doppler shift or a toroidal plasma rotation velocity of $\sim 42$ km/s

- Weak continuum interaction both in the core and near the edge
- This broad radial structure may couple core TAEs to the edge QC mode
NOVA-K finds a narrower n=10 mode at 576.4 kHz w/o Doppler shift

Mode is peaked further out with stronger continuum interaction in the core than in the H-mode case
Temperature and Density Profiles in L- and H-mode

- Stability calculations depend on input temperature and density profiles
- H-mode has a more peaked temperature and a steep pedestal compared to L-mode
- Density profiles are nearly flat
- H-mode density is nearly twice the L-mode density with a large steep pedestal
Transient L-mode effective fast ion temperature profile is broad with an on-axis maximum $T_H \sim 75$ keV

H-mode profile is steeper and peaked off-axis with peak $T_H \sim 55$ keV
H-mode has Higher Energy Density than L-mode

\[ \frac{\gamma}{\omega_{\text{tot}}} = \text{drive} - \text{damping} \]

\[ \frac{\gamma}{\omega_{\text{tot}}} = 0.1\% - 0.9\% = -0.8\% \text{ stable} \]

\[ \frac{\gamma}{\omega_{\text{tot}}} = 6.1\% - 1.1\% = 5\% \text{ unstable} \]

- Despite the lower fast ion temperature in H-mode the fast ion energy density is higher in H-mode and has steeper gradients than in L-mode
- Hence L-mode remains stable while H-mode is unstable to TAEs
Stability Effects of a Strongly Off-Axis Fast Ion Profile

Forcing an off-axis peaked fast ion profile increases TAE drive

- L-mode remain stable while the H-mode becomes very unstable!

\[ \frac{\gamma}{\omega_{\text{tot}}} = \text{drive} - \text{damping} \]

\[ \frac{\gamma}{\omega_{\text{tot}}} = 0.5\% - 0.9\% = -0.4\% \text{ stable} \]

\[ \frac{\gamma}{\omega_{\text{tot}}} = 37\% - 1\% = 36\% \text{ unstable} \]
Conclusions

- TAEs are often unstable in EDA H-mode but not in corresponding lower density L-mode plasmas with the same ICRF input power.

- These modes are observed to always rotate in the electron direction suggesting a hollow fast ion profile as found with AORSA/CQL3D in other discharges.

- NOVA-K modeling finds a spatially broad n=10 mode in H-mode that could couple the core to the edge QC mode and a narrower radial profile in L-mode that is peaked further out.

- TRANSP/TORIC5 fast ion profiles are peaked near the axis give only stable modes in L-mode and unstable modes in H-mode from NOVA-K analysis.

- Forcing an off-axis peaked fast ion profile increases TAE drive but the L-mode case remains stable while the H-mode case goes strongly unstable.

- Only modes in the ion direction are calculated to be unstable. Passing fast ions need to be included in the ICRF distribution in NOVA-K to properly model the drive in the electron direction.